Probing Dust Evolution with Gamma Ray Bursts

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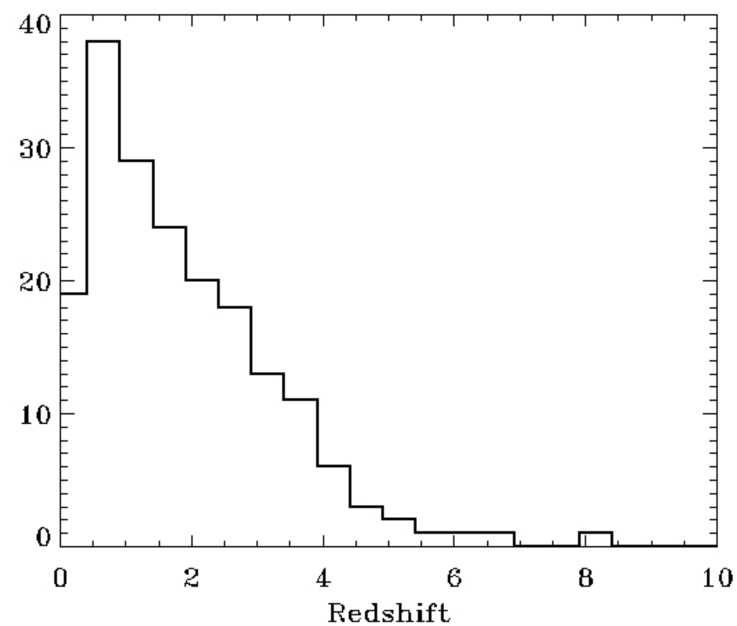
Goal

- To what extent can GRBs can be used as probes of dust in the early universe?

- GRBs trace star formation
- z_{max} = 8.2
- Simple power-law SED
- Construct a model of GRBs in evolving galaxies to discern the effects of dust on the SED



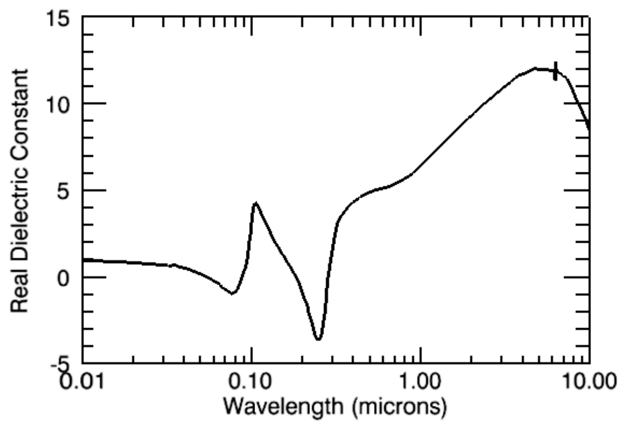
http://www.mpe.mpg.de/~jcg/grbgen.html

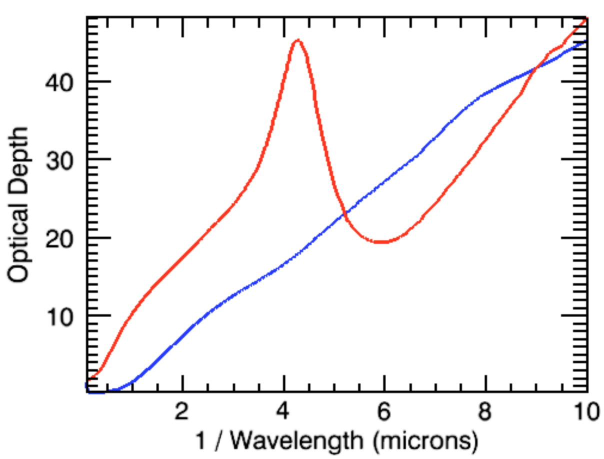
Dust Evolution

- Dust is formed in SN ejecta, in the winds and atmospheres of massive stars, and in the ejecta of classical novae.
- This study focuses on the two main sources of dust in the universe; SN and AGB stars.
- SN mainly form silicate dust (i.e., Cherchneff & Dwek 2010); AGB stars contribute graphite dust (i.e., Lagadec et al. 2008).
- Early universe should contain mainly silicate dust (Maiolino et al. 2006, Perley et al. 2010).
- Dust at moderate (2-4) redshifts includes carbon features (Krühler et al. 2008, Updike & Perley *in prep*.)

Modeling Dust Extinction

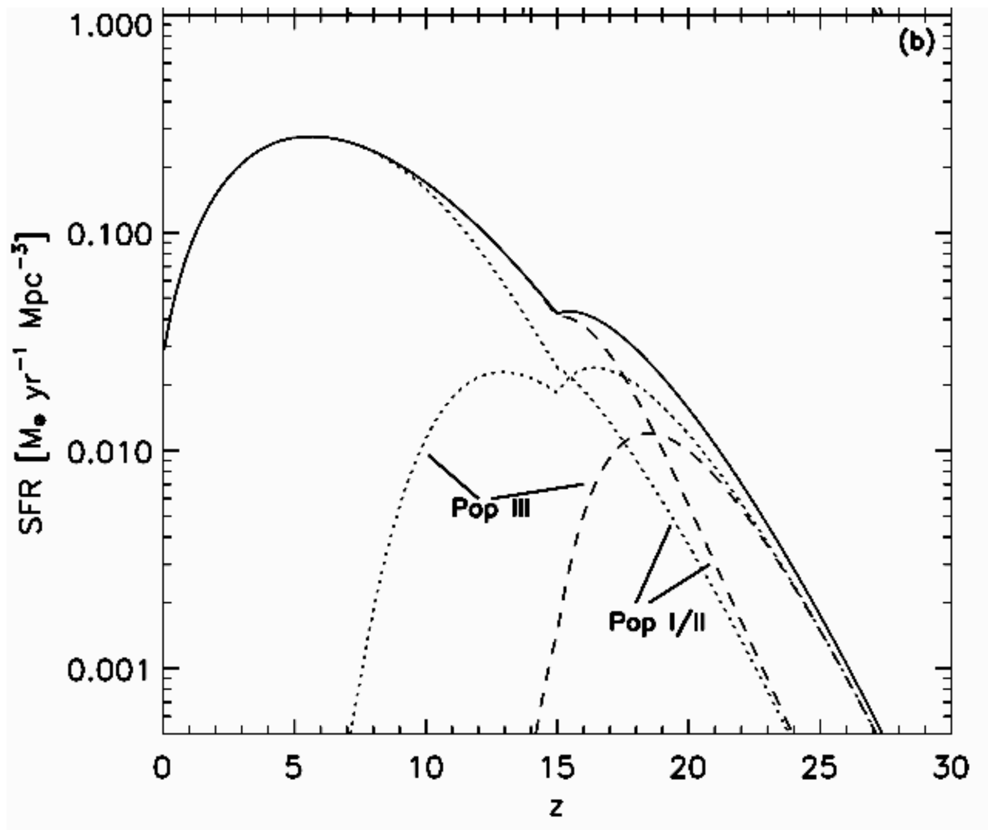
- Assume spherical particles with an MRN distribution between the sizes of 0.005 and 0.025 μm.
- Employ dielectric functions from Draine & Lee 1984, Draine 1985 (updated) for graphite and astronomical silicate.
- Explore extinction between 100 – 100,000 Å.





Dust in the Universe

- Dust properties = f(*z*)
- $SFR_{II}(z)$ and $SFR_{III}(z)$ from Bromm & Loeb 2006
- Assume all Pop III stars at 170 $M_{\odot}$
- Use a Salpeter IMF for Pop II stars using dust and gas yields given by Cherchneff & Dwek (2010) and Lagadec et al. (2008).



Bromm & Loeb 2006

Simple Galactic Evolution

- Disk galaxy with exponential dust distribution
- Disk evolves using models of Naab & Ostriker (2001)
- Galaxy begins with no matter, built up through exponential infall of pristine gas from the halo
- Instantaneous recycling approximation for supernovae; non-instantaneous recycling for lower mass stars

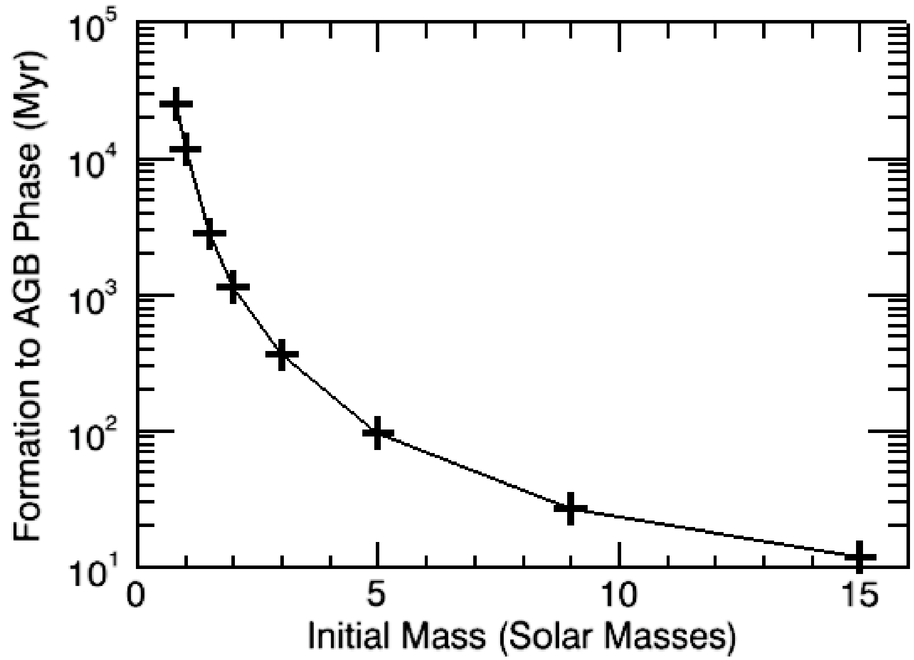
Galactic Dust Evolution

- Galaxy given some formation redshift
- 0.8 – 9 $M_\odot$ form AGB stars
- 9 – 100 $M_\odot$ form CC SNe

$$\dot{M}_g = -\frac{M_g}{\tau}(1-R) + \dot{M}_{in}$$

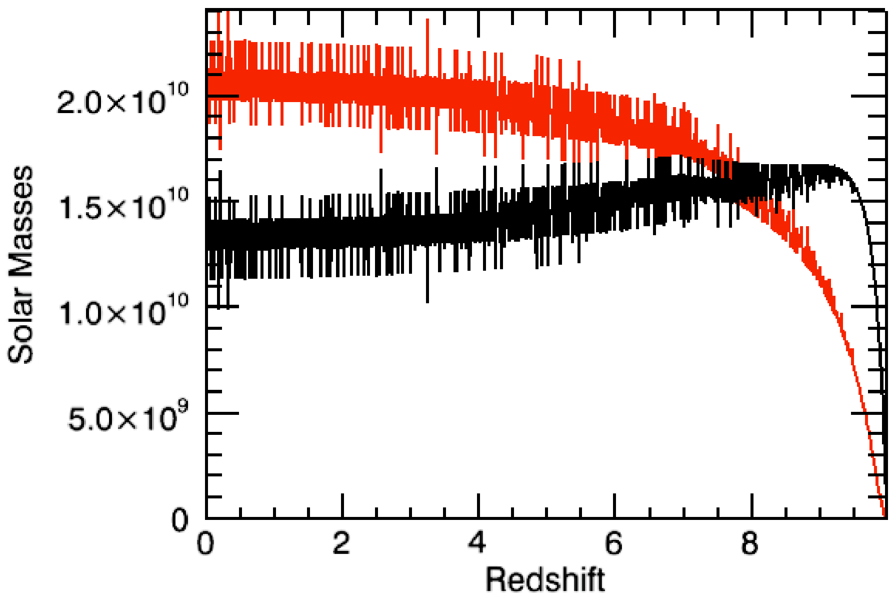
$$\dot{M}_s = \frac{M_g}{\tau}(1-R)$$

$$\dot{M}_d = \frac{-M_g}{\tau}\left(\frac{M_d}{M_g} - RY\right)$$

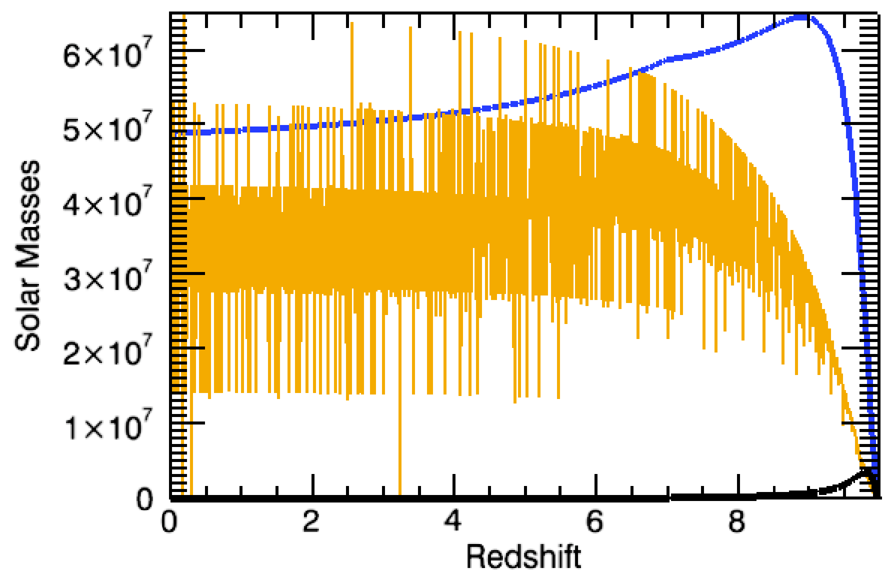


ages from Bernasconi & Maeder 1996 and Schaller et al. 1992

Galactic Dust Evolution

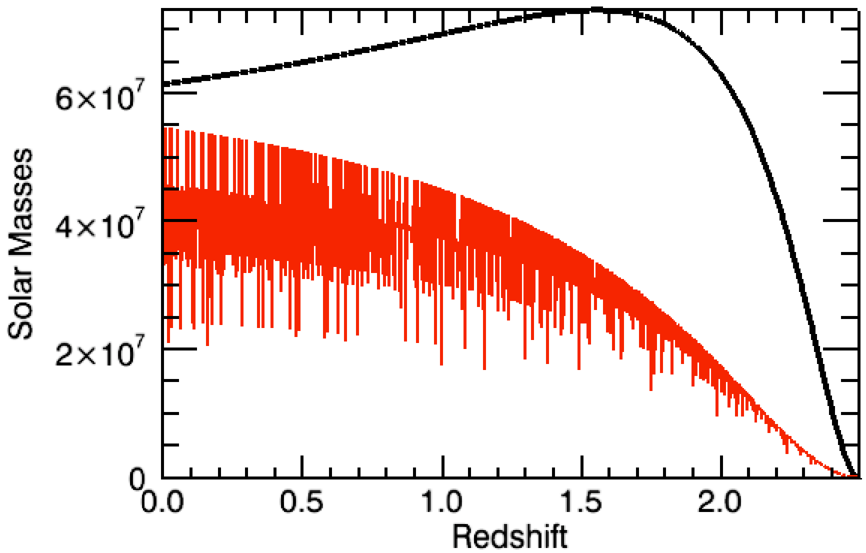


Silicate from Pop III stars, **silicate from Pop II** stars, and **carbon** as a function of redshift.



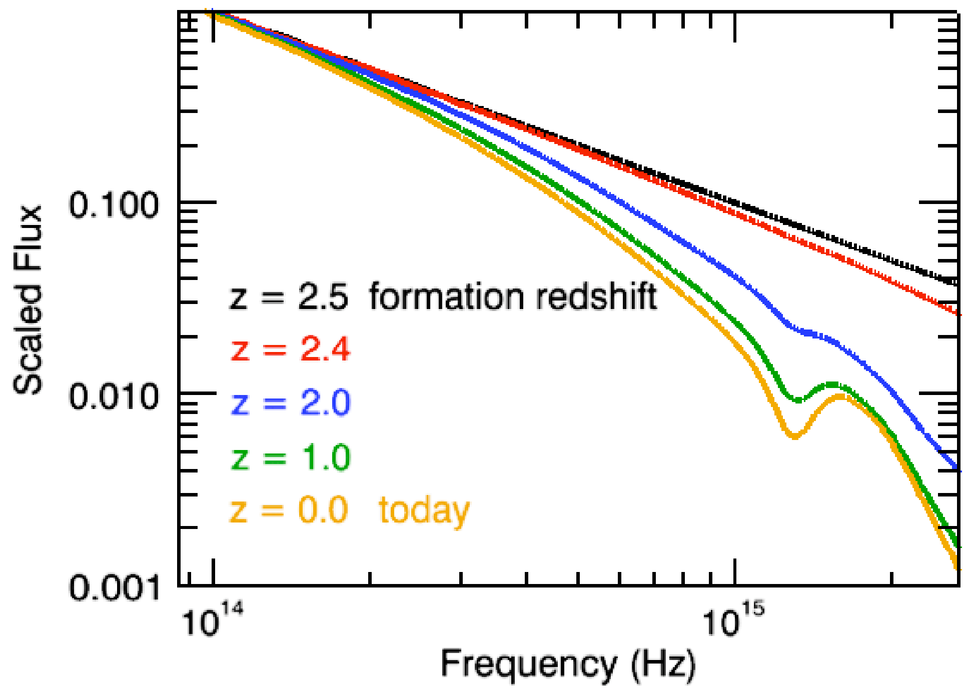
Stellar mass and **gas** mass as a function of redshift.

Galactic Dust Evolution in the MW



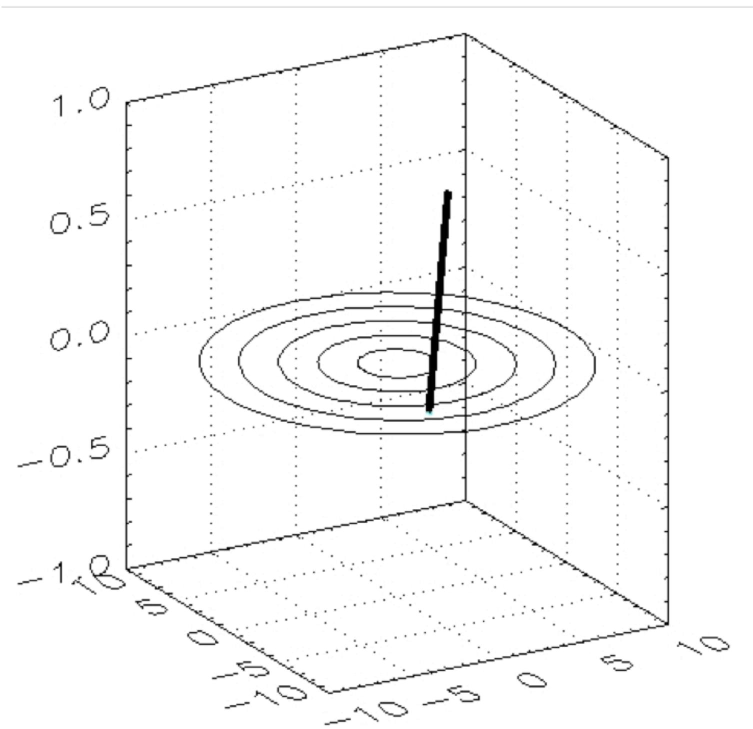
Silicate and **carbon** composition of the MW galaxy as a function of redshift.

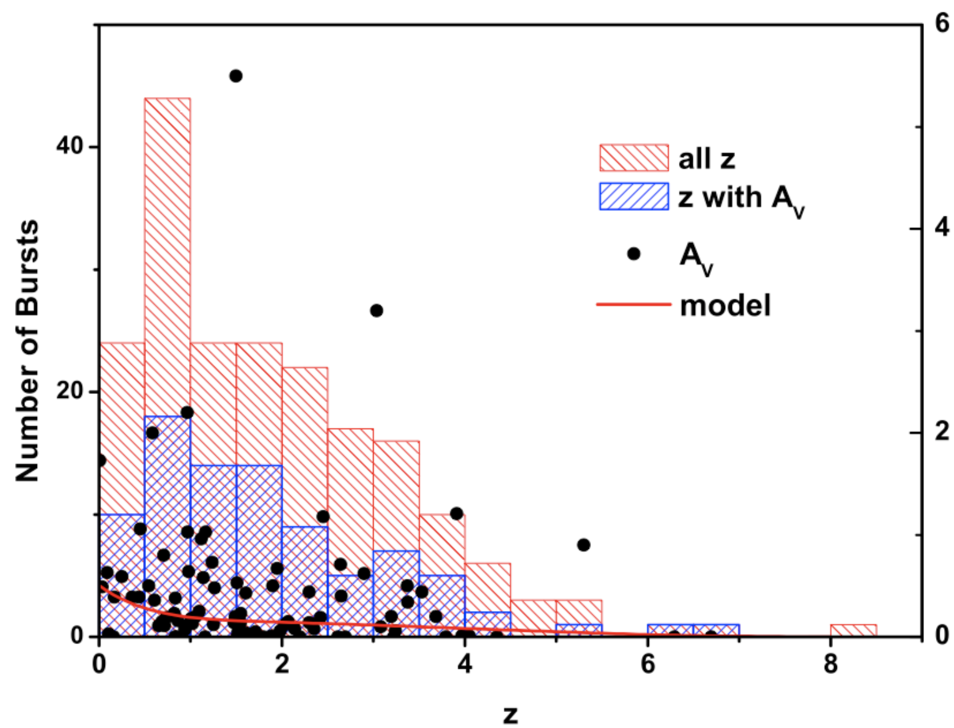
Evolving SED of a GRB viewed through the MW galaxy.



GRBs as Probes

- MC simulations of GRBs observed through dust in the host
- Compared to A_V measurements from the literature

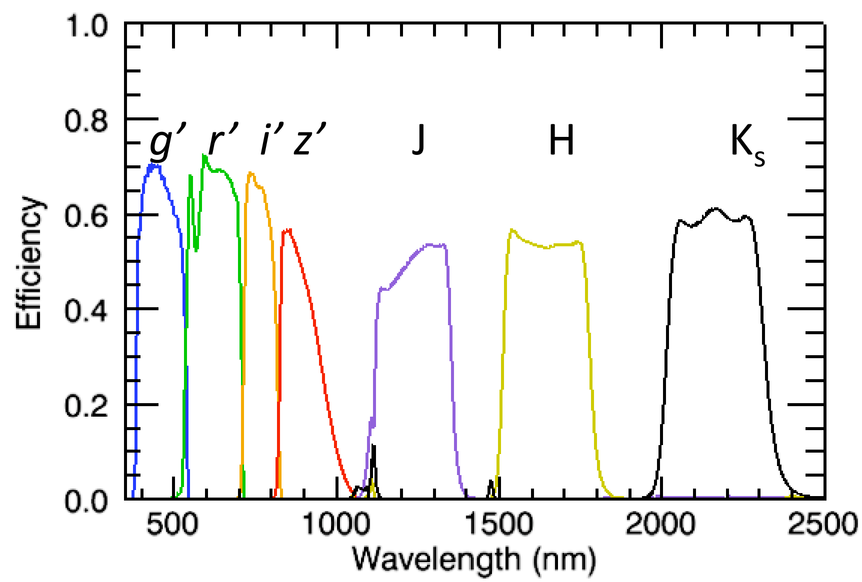




GRBs as Probes

- GROND is a 7-band imager capable of simultaneous SEDs.
- Large homogeneous data set; >50 GRBs with spectroscopic redshifts
- Optical and NIR bands; probe dust from z = 0 to 5.2
- Can be extended further with mid-IR data or spectroscopy

GROND Filter Curves



Fitting the Extinction Curves

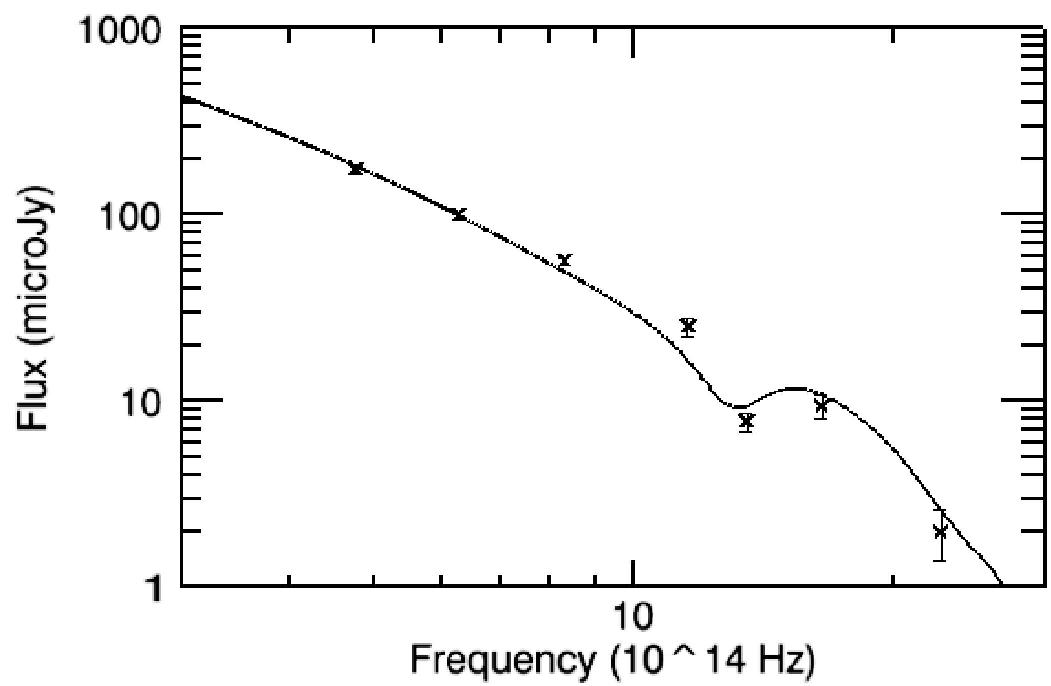
- 4 parameter fit to GRB SED $$F = F_0 \nu^{-\beta} e^{-(\Sigma_g \sigma_g + \Sigma_s \sigma_s)}$$

Preliminary fit to SED of GRB 070802

Graphite column density
$(2.34 \pm 0.33) \times 10^{11}$ cm^{-2}

Silicate column density
$(5.04 \pm 0.62) \times 10^{11}$ cm^{-2}

$\tilde{\chi}^2 = 6.81$



GROND data from Krühler et al. 2008

Preliminary Conclusions

- Dust evolution is expected
- Signatures of dust have been observed in GRB SEDs
- Large MC simulation of a galaxy population needed for detailed GRB SED evolution
- GROND data set is a good place to start